Decarbonisation Roadmap for a Sustainable and Competitive Indian Aluminium Industry

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Abstract

The Indian aluminium industry is a cornerstone of the nation's industrial growth, supporting sectors like infrastructure, transportation, and energy. However, its dependence on coal-based power for smelting and refining makes it one of the highest carbon-emitting industries. As India pursues its commitment to achieving net-zero emissions by 2070, decarbonisation of the aluminium sector is crucial for balancing industrial expansion with environmental sustainability. Transitioning to renewable energy sources, such as nuclear and adopting emerging technologies like green hydrogen and carbon capture will play a pivotal role in reducing emissions. Additionally, enhancing energy efficiency through advanced smelting techniques and increasing the share of secondary aluminium production can significantly lower the industry's carbon footprint. Promoting a circular economy through increased recycling, policy-driven incentives, and stricter emission norms will further accelerate the transition.

Collaborative efforts between the government, industry stakeholders, and research institutions will be essential to create a sustainable and competitive aluminium sector that aligns with India's broader climate action goals. A structured roadmap integrating technological advancements, policy support, and investment in green alternatives will ensure that the Indian aluminium industry remains a global leader while meeting its decarbonisation targets.

Keywords: Aluminium, Carbon, Decarbonisation, Sustainability.

1. Introduction

Aluminium is among the most widely used metals worldwide and is the fastest-growing segment within the non-ferrous metals sector. Due to its lightweight, strength, and recyclability, aluminium plays a vital role in modern industrial applications and ranks second only to steel in terms of global consumption volumes. However, India's per capita aluminium consumption is still relatively low 2.6 kg compared to the global average of 11 kg – indicating significant potential for future growth [1].

1.1 Role in Economic Growth and Industrial Development

The Indian aluminium industry is a strategic contributor to the nation's economic development, supporting critical sectors such as infrastructure, power transmission, transportation, packaging, and renewable energy. Aluminium's high strength-to-weight ratio makes it a preferred material for electric vehicles, aerospace, solar panel frames, and wind turbine components. In particular, the power sector remains the largest domestic consumer, with aluminium widely used in conductors and cables for electricity transmission and distribution. As India advances its industrialisation and clean energy transition goals, aluminium will continue to be integral to achieving sustainable growth.

1.2 Current Production and Energy Consumption

Despite its advantages in end-use applications, aluminium production is highly energy-intensive and contributes significantly to industrial greenhouse gas (GHG) emissions. In 2019–2020, the Indian aluminium industry emitted approximately 77 million tonnes of CO_2, accounting for nearly 9 % of the country's total industrial emissions [2]. The major emission hotspot lies in the smelting stage, which is predominantly powered by captive coal-based electricity, responsible for nearly 85–90 % of total emissions from the aluminium value chain. alumina refining also contributes significantly to the carbon footprint due to high thermal energy requirements.

India has an installed aluminium production capacity of 4.1 million tonnes per annum and actual production during financial year (FY) 2023-2024 is shown in Figure 1 [3-5]. In FY 2023–2024, India accounted for 6 % of global aluminium production, with the remaining 94 % contributed by the rest of the world, underscoring India's growing presence in the global aluminium industry while highlighting the need for sustainable growth strategies [6]. The production facilities are largely concentrated in eastern India, particularly Odisha due to the availability of bauxite and coal. Secondary aluminium production constitutes nearly 31–35 % of the total aluminium produced in India. The sector is highly fragmented and largely unorganized, and heavily dependent on imported aluminium scrap. Notably, about 56 % of India's aluminium imports are in the form of scrap. The secondary aluminium sector's contribution is expected to grow, with recycled aluminium projected to see a compound annual growth rate (CAGR) of around 8 % in the near term.

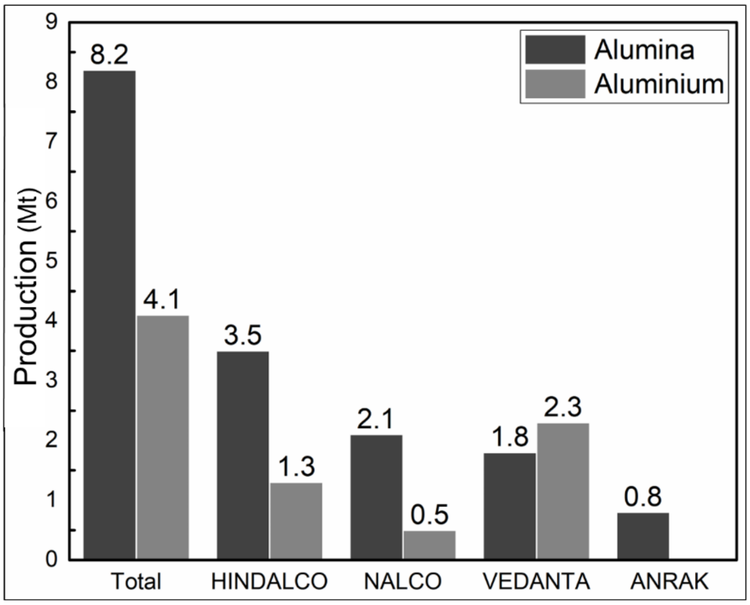

Figure 1. Primary aluminium and alumina production in India during FY 2023-2024.

In India, bauxite refining consumes approximately 5 600 kWh/t Al, significantly higher than the global best practice of 4 400 kWh/t Al. In the smelting phase, India's electricity consumption ranges from 13 700 to 15 300 kWh/t Al, which is on par with the global average of 14 091 kWh/t Al (see Figure 2) [3, 5, 7]. These figures highlight the urgent need to decarbonise the sector, particularly by adopting cleaner technologies.

4. Conclusions

Achieving meaningful emissions reductions in the aluminium sector requires a portfolio approach – combining readily available, cost-effective technologies with strategic investments in high-impact, capital-intensive solutions. Policymakers and industry leaders must overcome financial, technical, and operational barriers to accelerate the adoption of underutilised measures. A coordinated, phased implementation – guided by robust data and continuous innovation – is essential to align the sector with global climate goals.

The analysis underscores the contrast between widely adopted, low-cost solutions and high-impact measures that remain underutilised due to significant investment or operational hurdles. A balanced, holistic strategy that integrates both incremental improvements and transformative technologies will be key to advancing decarbonisation.

- Adoption vs. Impact: Technologies with high diffusion rates (e.g., smart pot controllers, graphitised cathodes) often correspond to those with negative or low marginal abatement costs, indicating that cost-effective solutions are more readily adopted.
- Cost vs. Potential: Some high-impact measures (e.g., RE-RTC integration) have both significant abatement potential and high investment requirements, posing financial and operational challenges for widespread adoption.
- Strategic Prioritisation: The analysis highlights the need to balance immediate, cost-saving interventions with longer-term, capital-intensive strategies to achieve deep decarbonisation.

5. References

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